Workshop on New Visions for Networking Research and Applications March 12-14, 2001

May 11, 2001

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- Goal: to stimulate bold thinking in networking research; to explore objectives that might be realized 10-20 years out; to identify the steps to get there

  -what does the research community consider challenging & important?

  -map them into mission goals/visions

  -develop new programs

- White Paper Solicitation (approx 80 papers)

- 160 invited participants (university, industry, feds; diverse group)

Workshop Structure

- Day 1: Panel Briefs & Discussions
  around three broad themes:
  - -Adaptive networking
  - -Infrastructureless networking
  - -Heterogeneous networking
- Day 2: Breakout Disscussions around five scenarios
  - -crisis management
  - -networked medical care
  - -collaborative research
  - -scientific research: high energy physics
  - -military tactical : network of sensors & robots
  - -logistics: pervasive, global inventory/tracking system
- Day 3: Readouts from Breakout Leaders

Example White Paper Titles

- Disposable Networks: Automating Network Management for Short-Lived Networks
- Quantum Network Protocols
- Large Scale Networking for Particle Physics
- Architectural Implications of Unlimited Bandwidth
- Thought Communications
- Adaptive Networking Architecture for Service Emergence
- Distributed Real Time Control over Large Scale Networks
- Autoconfigurable Addressing and Routing Protocols for Large Scale Networks
- Accurate Target Definition Enabled by High Speed Networks
- Ubiquitous Reconfigurable Wide Area Sensor/Actuator Networks
- Towards A Ubiquitous Disaster Information Network
- Moving Towards Massively Scalable Video-Based Sensor Networks
- Toward Disappearing Reality

no timeless jargons :

self-organizing, auto-configuring, ad-hoc, adaptive,scalable, secure, seamless

What we were looking for *specific* ideas:

Long Term Vision –20 yrs out

What can we do in the next 5 years

Examples, Metrics, Possible Approaches

Is it extremely challenging, technically?
At the same time, is it feasible?

Two Threads

High-Capacity

-networks enabling distributed, real-time, collaborative scientific research

-military: global reachback

Pervasive, Fine-Grained

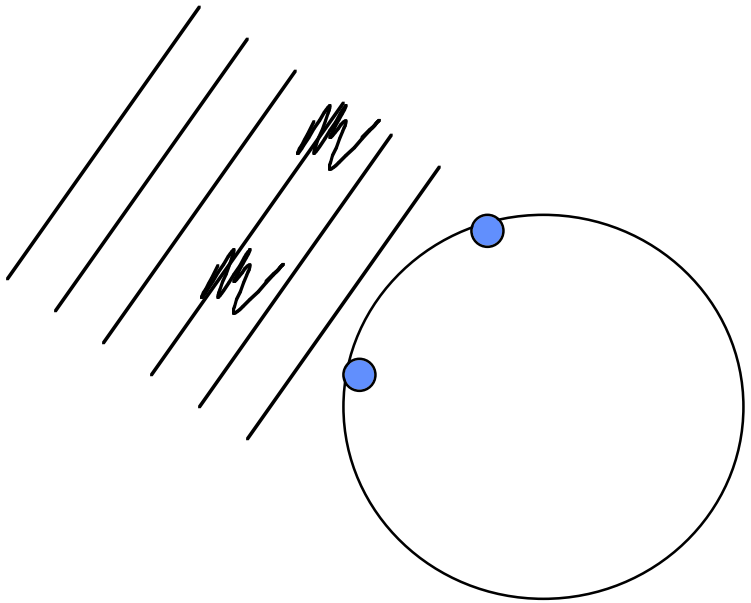
-military: networking of sensors, robots, to support logistics, autonomous manifest

Networks to help Scientific Research

- High-energy nuclear & particle physics
- 1 network engineer = 2 physics postdocs
- highly stressed, challenging environment
- characterized by compute-intensive, data-intensive, bw-intensive, distributed collaboration, multi-national-admin domains
- creative & innovative community
- generic approach vs. vertically integrated solutions

Networks to help Scientific Research

- Radio Astronomy and Networked Real-Time VLBI (Very Long Baseline Interferometry)
- Many national and international VLBI sites
- Today, all use non-real-time interferometry (timestamp, transfer data & correlate)



•study of sources, study of geodetic features, high-precision time
•real-time requires Gbps+ between VLBI sites
•enable real-time experimentation (real-time verifications, study of transients)
•ALMA: 120 Gbps

Fine-Grained

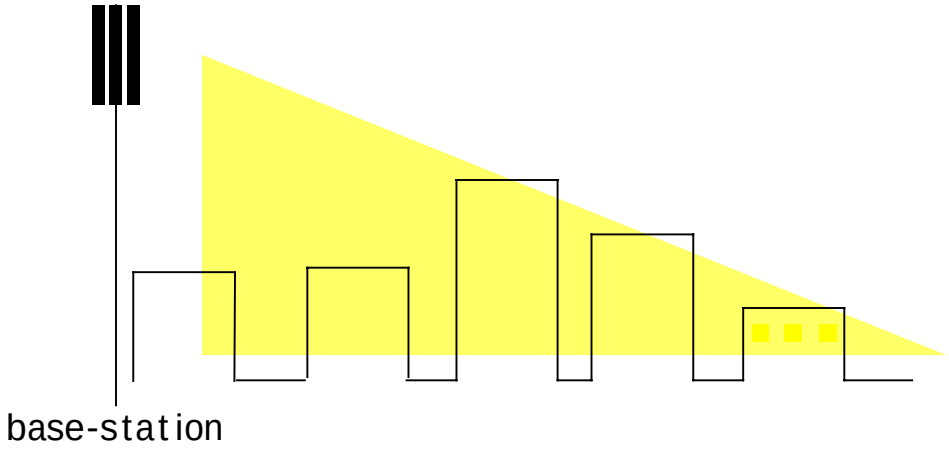
- Characterized by densely networked nodes (sensors, robots, logistics, vehicles, condition-based maintenance..)
- Issues: PHYS, MAC, DATALINK, NETWORKING & above
  - -rapid dynamic deployment with minimum human intervention
  - -self-organization guided by high-level constraints (e.g. administrative structure, tasking constraints etc.)
    rather than today's unconstrained self-organization/
    clustering for scalability research
  - -trust and security
  - -low-energy wireless and power-aware networking
  - -throw-away low-cost
  - -robust & efficient PHY and MAC layers --> works in urban and other RF non-friendly harsh environment; need improvements over today's csma schemes

Urban Presence & Combat

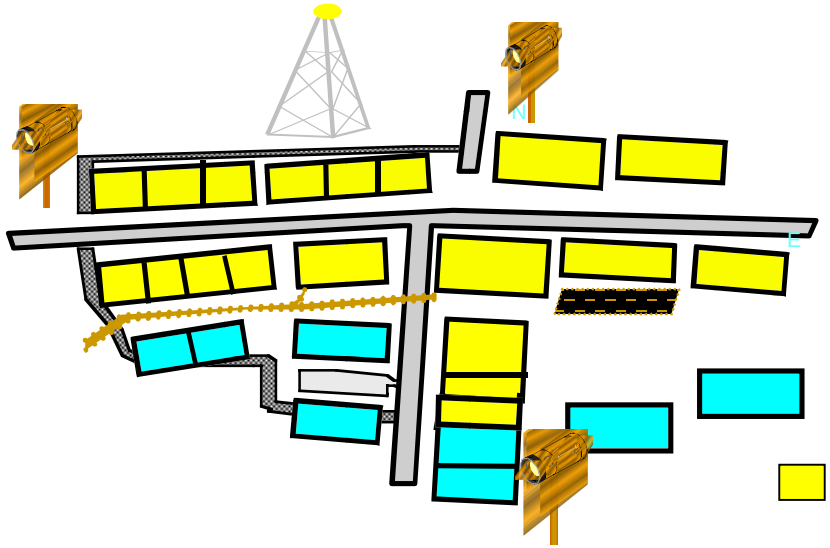
- **Since 1977, US forces have been involved in over 25 major military interventions. 10 in urban environments; 11 in combined urban/rural settings.**
- **Presently 14,000 U.S. military personnel are deployed in urban environments, mostly in Bosnia and Kosovo.**
- **Today, half of the world's population lives in urban area. By 2024, the figure is expected to reach 85%.**
- **Army and USMC estimate urban operations may require nine times the ground forces of operations on open terrain. Grozny casualty rates were 65%; recent MOUT exercises, casualty rates reached 70%.**
- **Importance of future missions to capture, defend, neutralize within an urban area ; also civil support in the US (crisis response)**

How is it done today?

Cellular Infrastructure



- fixed infrastructure
- pre-designed deployment



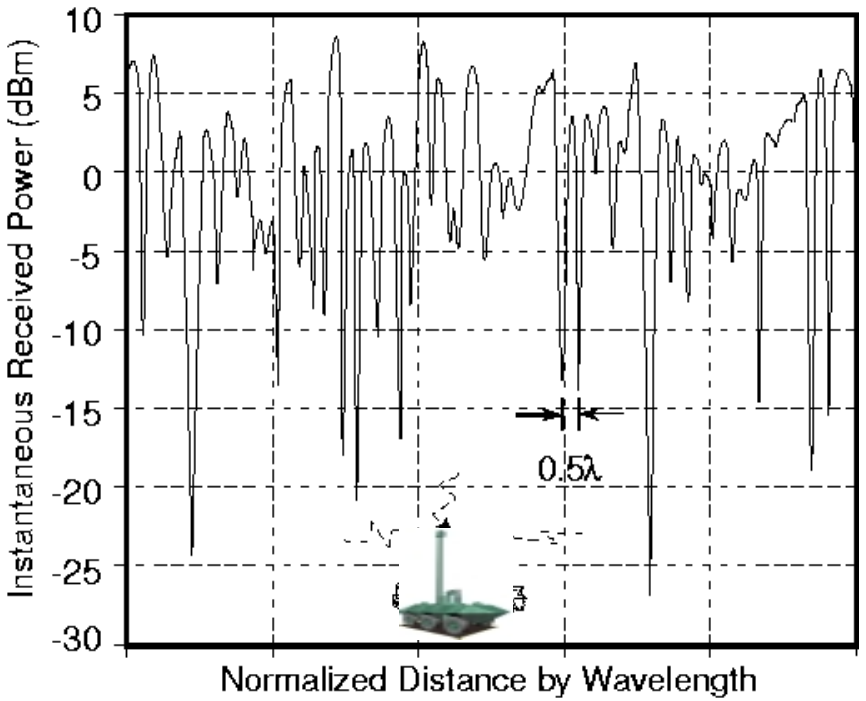
Ft. Benning McKenna MOUT Site

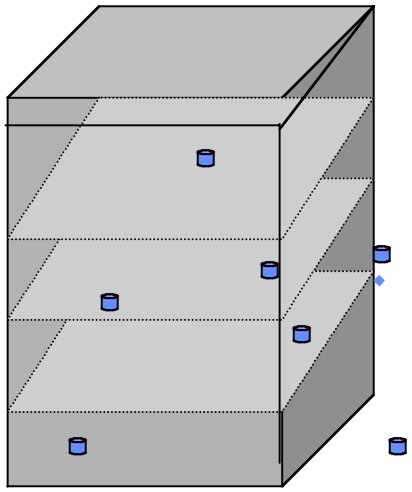
•pre-instrumented with cables, fiberoptics, towers, wireless LAN

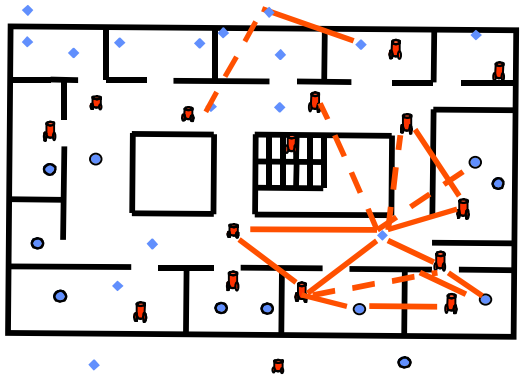
harsh multipath environment

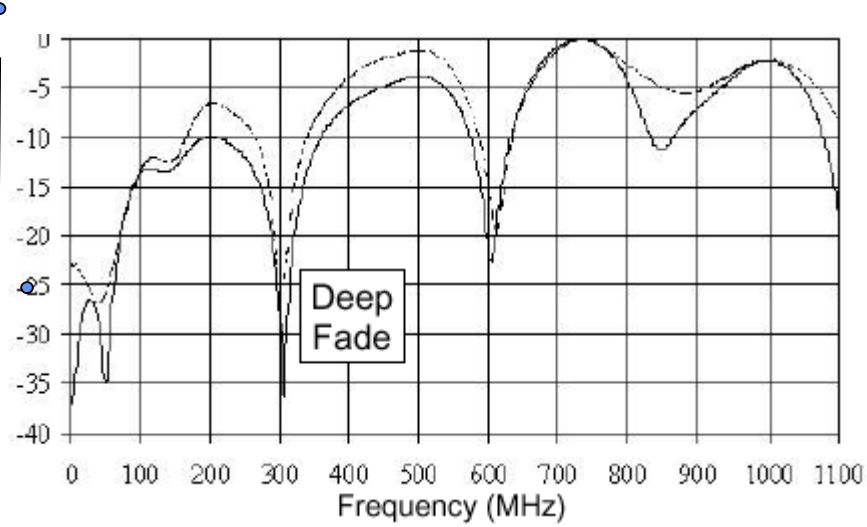
•destructive interference of RF sinusoids can induce multipath fading and dropouts

•causes intermittency, outages, unidirectionality in network links

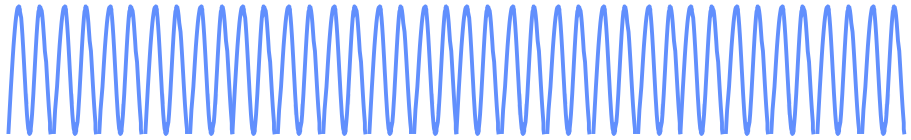






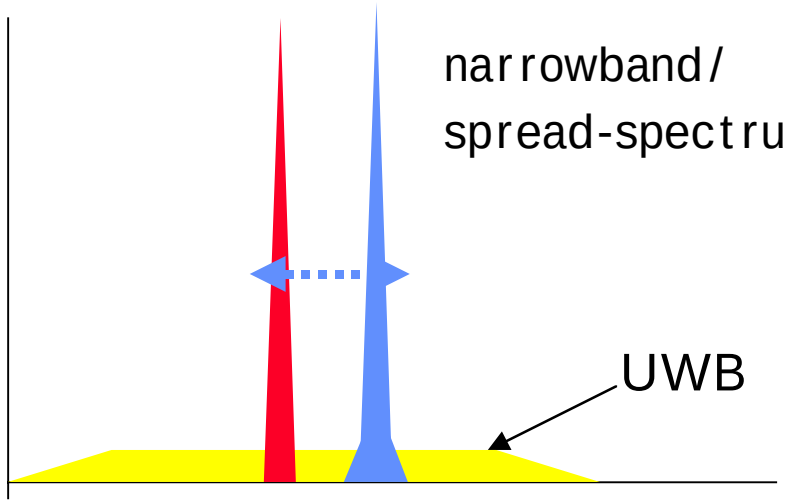


Traditional Wireless: RF PHY



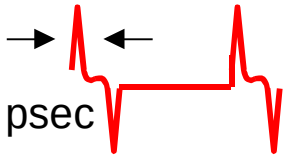
sinusoidal narrowband

•secure waveform (lpd, lpj)



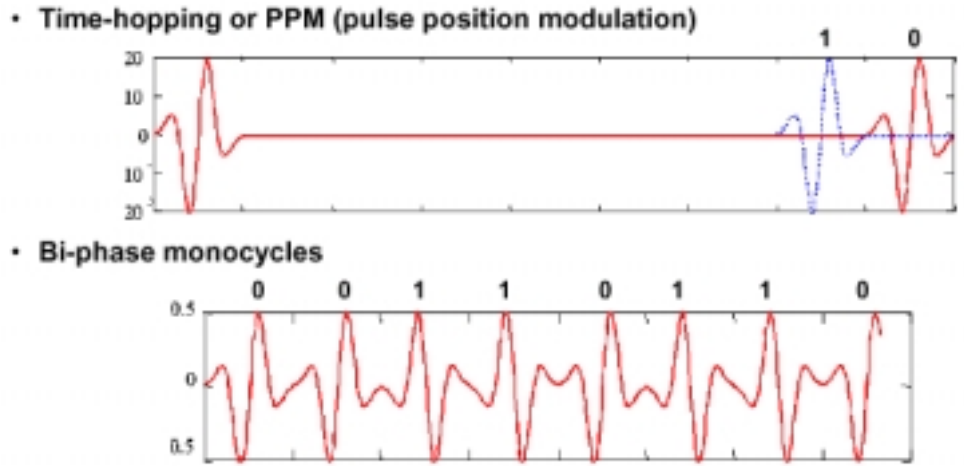
Ultrawideband Networking

•short pulse waveforms
("carrier free", "impulse")



•large fractional bw: $2\,\frac{f_H - f_L}{f_H + f_L}$

•broad spectrum :
100's MHz to multi-GHz
-LPI
-narrowband interference rejection (limited LPJ)



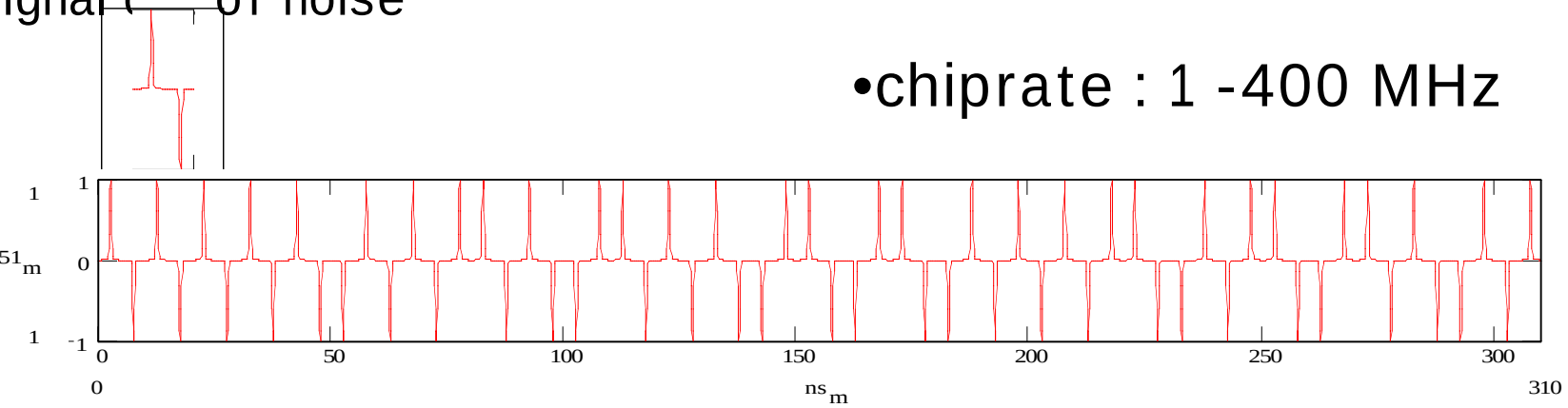
UWB Fine-Grained Networking

- possible to demonstrate large range or high bw
  - 1km or 100 Mbps
- regime of interest for fine-grained networking
  - short range: 10's to 100's meters
  - low bit-rate (typically 10 kbps, but can also go up to 10 Mbps)
  - low power operation
- use code and coherent combining/correlating receiver to pull signal out of noise

1 bit

vs

1 bit=100 chip seq.



- chiprate : 1 -400 MHz

Hardware Prototype

- Pager-sized 4th Generation Prototype

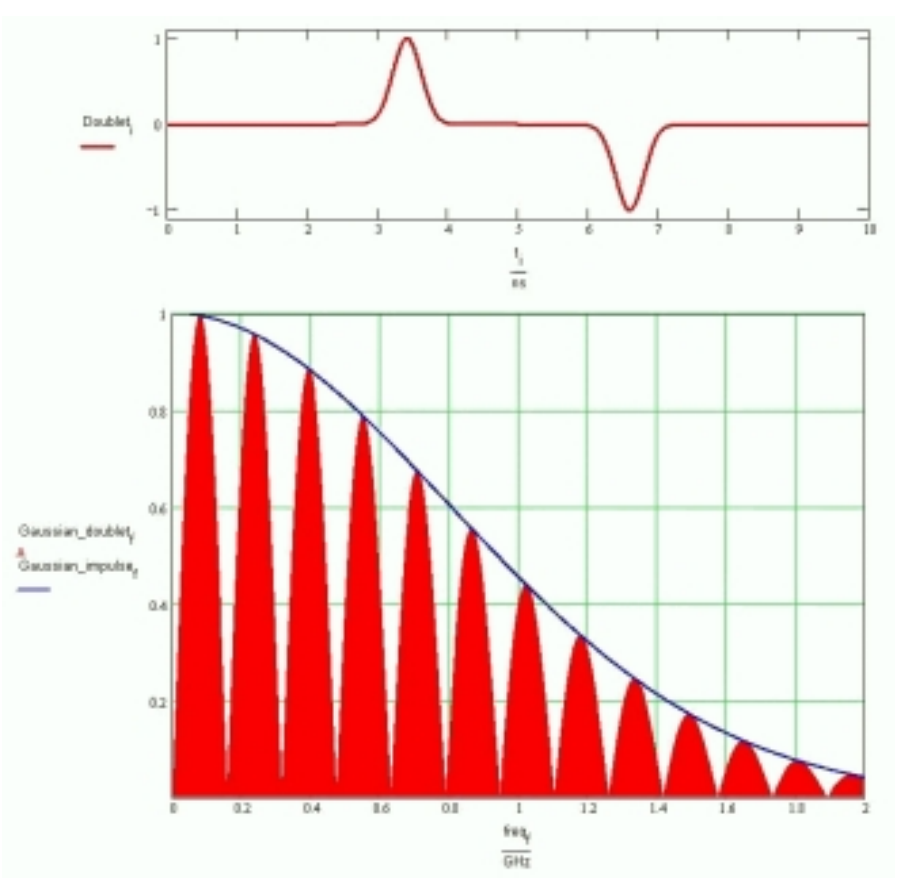
  Transmit/Receive
  - Rx/Controller chip (Aether5)
    - Closed loop sensor
    - Low-noise TCXO
  - Tx Antenna Driver chip (Driver2)
    - Large Current Radiator
  - External RF amplifier & DAC
  - A-to-D converter

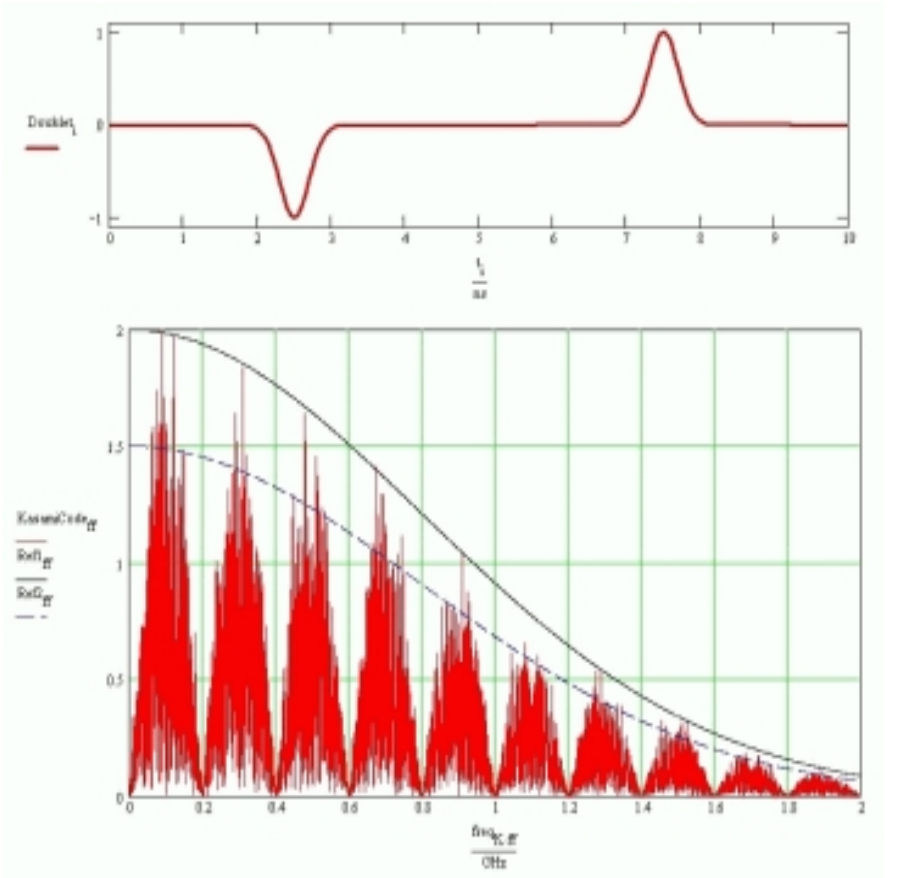
  Processor
  - Motorola ColdFire 5204
  - 1MB Static RAM
  - 512KB Flash RAM

  Power regulation

Signal Spectrum

- Spectral Nulls chosen by Impulse Separation to notch out selected frequency bands for transmission & reception (*i.e.* GPS)





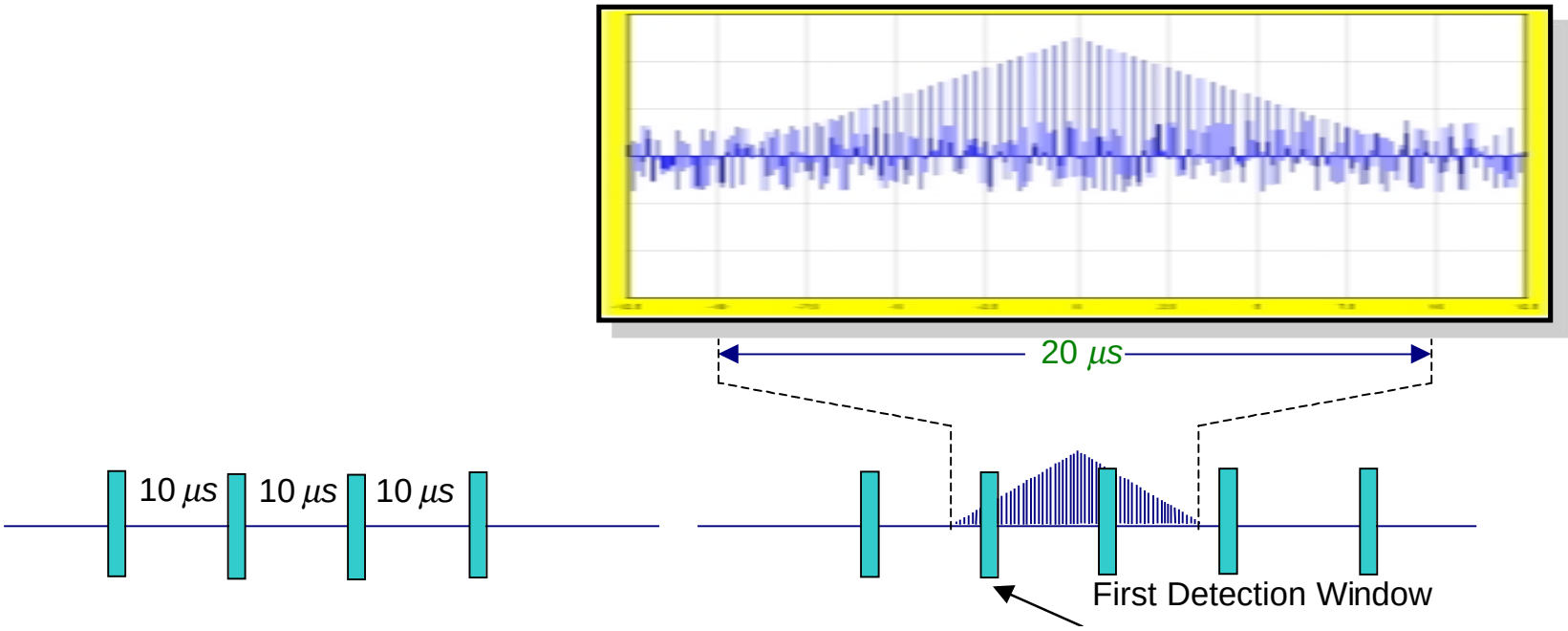
UWB Networking

Algorithms, Protocols, and Distributed Network Control
for robust, scalable ad-hoc UWB networking

(100,000 - 1 million nodes in 1km^2)

Challenges

- precision time-based ad-hoc network
- self-organization & robustness using software controlled adaptation
- modular design and open interfaces to enable 'inter-stack' awareness



Cooperative Networking

- Position location using inexpensive timebases

  Quartz crystal or MEMS oscillator

  - 1 ppm (10^{-6}) with on-chip software-mediated temperature compensation
  - Localizers track each other's clock frequencies for ppb (10^{-9}) matching

  Absolute position accuracy of entire network is raised to the absolute accuracy of the best oscillator or known distance

- Code & Time Division channelization for a million Localizers per km^2
- Multi-hop communication

  Defeats $1/r^n$ received power reduction ($n \geq 3$)

  Reduces probability of intercept

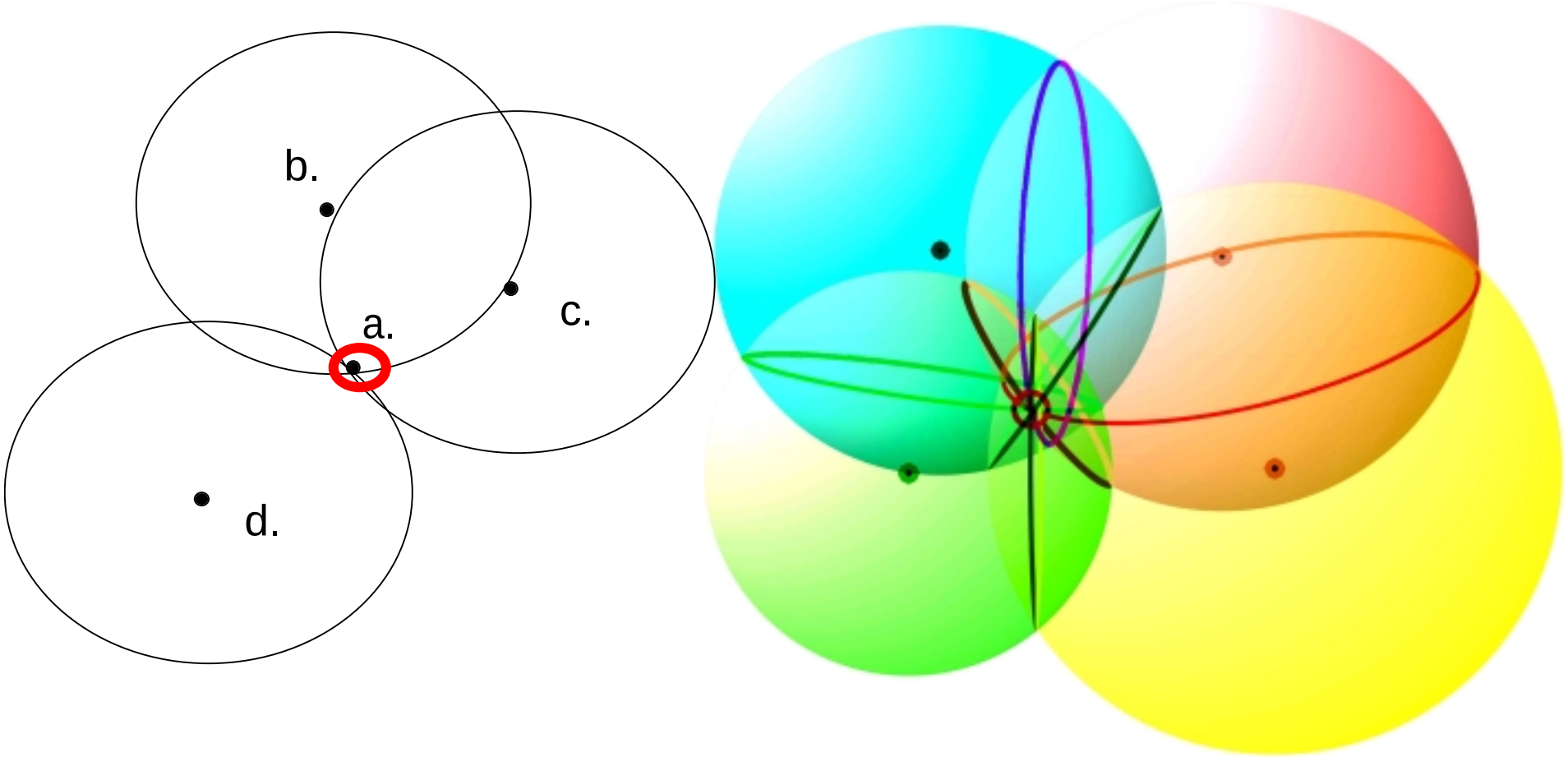
- Selective sharing of data over network
- Capable of hiding ranging information (for Security)

  Synchronization without giving range

  Spoofing for privacy

Peer-to-peer Network Geo-localization Techniques:

- Pair-wise ranging protocol
- 3-Dimensional Multi-lateration



Alternative, Emerging Wireless Networking PHY Layer

- Desired features:

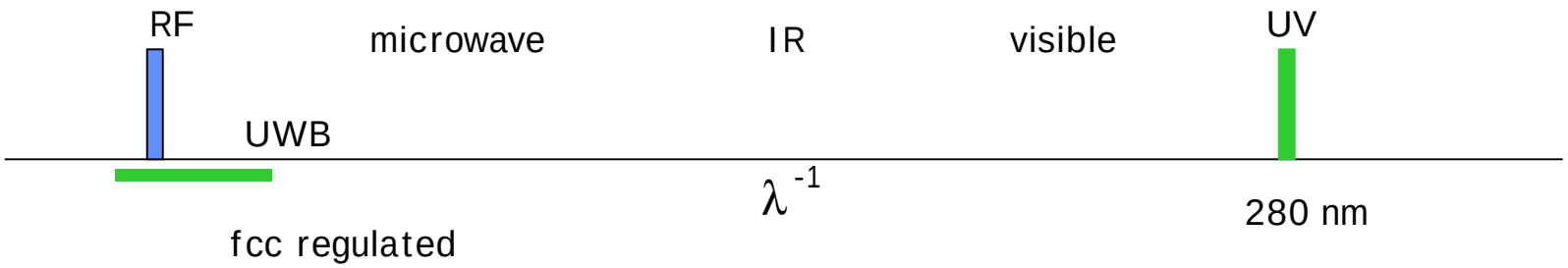
  low power, small, potentially low cost

  secure, difficult to detect (LPD, LPJ)

  non-line of sight; immunity to multipath

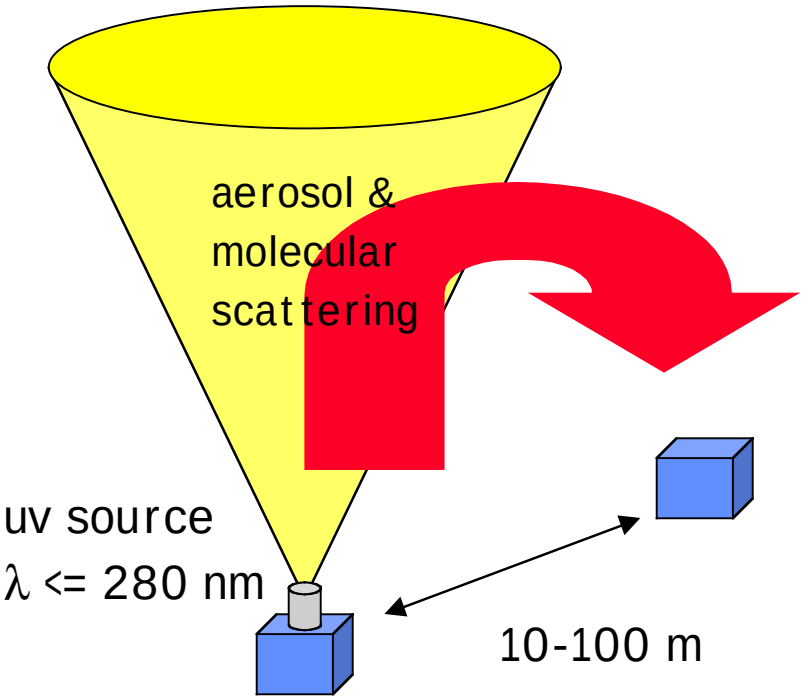
  immunity to groundwave loss (low elevation signal loss)

an example:
uv wireless



Networking in the UV:

atmosphere absorbs
and scatters UV



compared to RF:

- non-line-of-sight
- orders of magnitude lower in transceiver power power
- highly confined signal - exponential loss above 0.8km

Detectability from airborne ELINT platform

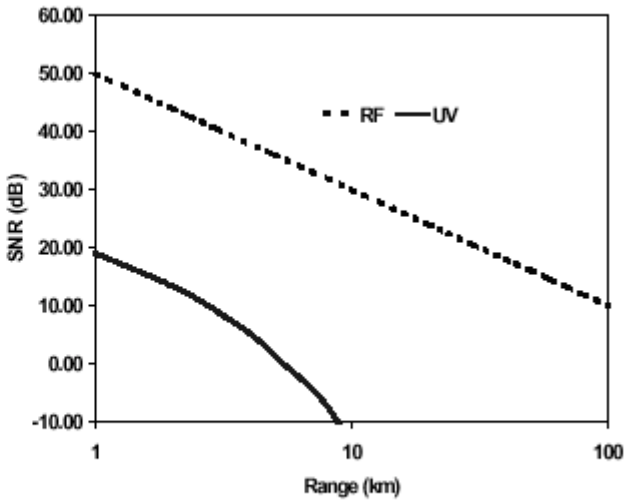


Figure 12. Detectability of UV versus RF ground communication signals from an airborne ELINT platform

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Open System Solutions

- systems pull vs technology push
- vertically integrated (point-) solution vs open, generic approach
- e.g. of Systems programs:

  self-healing mine, small units -situational awareness ,
  offensive radio jamming, army's Future Combat System